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Water for a Healthy Country

The Past, Present and Future of Sediment and Nutrient Modelling in GBR Catchments

Outcomes of a workshop held 1-2 November 2006
at the Hotel Grand Chancellor, Brisbane

Post, D. A., Waterhouse, J., Grundy, M. and Cook, F.

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Executive Summary

Effective research into, and delivery to clients of catchment sediment and nutrient modelling is of increasing importance in Queensland. The generation, transport, storage and impact of sediments and nutrients is a complex and disputed area – and the need for a coherent and transparent strategy for modelling is recognised by planners, policymakers, governments and scientific institutions. There are clear, specific drivers in geographic areas as well; especially in the catchments of the Great Barrier Reef (GBR) and the Reef itself, the streams of south-east Queensland and in Moreton Bay, in many of our regional body areas, near-shore fisheries and in a number of specific impacted areas. The water quality issue is also increasingly intertwined with the issues around ensuring adequate water supply and quality for urban and agricultural use and for environmental purposes. There is real demand for effective, strategic modelling. Progress in strategic modelling in Queensland in response to these issues is also likely to have national application.

A workshop was held on 1 and 2 November 2006 in Brisbane to discuss the past, present and future of sediment and nutrient modelling in GBR catchments. This workshop was important for a number of reasons, but perhaps none more than the fact that it brought sediment and nutrient modellers from CSIRO Land and Water (CLW) and Queensland Department of Natural Resources and Water (NRW) together with policy makers and the users of the information provided by these models. While this had happened on an ad-hoc or as-needs basis in the past, this was the first time that such a workshop had been held outside the bounds of individual projects. This gave the participants the chance to freely exchange ideas without project constraints. The opportunity for interaction between researchers from CLW and NRW should also not be understated as such interaction in the past has typically been on a project level.

Prior to the workshop, CSIRO coordinated the development of a statement delivered by a cross-section of science and policy leaders in catchment and water ecosystem management in Queensland and elsewhere (Attachment 1). The statement provided a message to scientists attending the workshop to stress the importance of the modelling work, the need for a coherent and understood strategy, and provided a mechanism to underline the level of support to collaborative approaches.

The workshop was structured around four main sessions: (i) introducing the consensus statement and reiterating the needs of the users; (ii) reviewing past approaches to sediment and nutrient modelling; (iii) assessing the current approaches; and (iv) recommendations for the future.

An overview of the workshop is provided in this report, followed by details of individual sessions, presentations, and discussion sessions in the Attachments. Of significant importance for defining the direction of future collaborative projects, a number of key areas of further research and future challenges were identified and agreed by workshop participants. These were divided into 7 groups:

1. **Sediment dynamics:** Storages of sediment in the catchment must be accounted for. This is essential to determine the time lags and magnitude of changes in sediment loads due to management interventions. This may require a temporally-explicit modelling approach.
2. **Hydrology:** The main driver for transport of sediments and nutrients in the landscape is water, so to improve our understanding of sediment and nutrient transport requires improved understanding of hydrological process. In particular, it is necessary to incorporate linkages between groundwater and surface water in the modelling approach. This must be accompanied by a move to a more temporally-explicit model incorporating event based approaches.
3. **Nutrients:** Because of differing bio-availability, speciation of nutrients is required, rather than considering just total nitrogen and total phosphorus. Other dissolved contaminants must also be modelled (eg. pesticides).
4. **Scaling:** Landscape processes such as hillslope delivery of sediment need to be understood and modelled at a finer spatial and temporal resolution. Knowledge of how to scale up and down processes, parameters and data is relatively weak. Key areas that are often poorly understood and ignored in current models are interfaces, eg. hillslope/stream, surface/groundwater, river/estuary.

5. **Data:** The landscape is generally poorly characterised, and input data for the models needs to be measured at finer spatial and temporal resolutions that at present. This is particularly true for rainfall, digital elevation models, soils and water quality measurements. Data capture (long term), data management and data sharing (including data discovery) issues should be addressed in a collaborative manner.

6. **Uncertainty:** Uncertainty in our model structures, inputs and outputs needs to be explicitly recognised and routinely reported. Confidence limits need to be placed on all model predictions. Ways to effectively communicate uncertainty need to be investigated and developed.

7. **Links to management and policy:** Effective communication between project members, researchers, modellers and the end users of the information coming out of sediment and nutrient models is essential. This communication should begin before the project starts and must continue right through the project, culminating in an effective dissemination of results to the end users. While this may sound obvious, it is frequently overlooked. Numerous examples were given during the workshop where projects failed because of a lack of effective communication. Furthermore, linking catchment scale modelling to paddock scale production, and catchment models to receiving water models are critical knowledge gaps to drive management intervention.

The workshop participants agreed that these seven objectives can only be achieved through a more strategic, coordinated and collaborative approach to modelling in the GBR, which attempts to address system-wide issues (connectivity between catchments, estuaries and the Reef). The models should be characterised by transparency, definition of uncertainty and communicability, and strive for the capacity to incorporate variability such as climate change, events and regional differences. Development and application of the models needs to be intertwined with users to ensure that the models are fit for purpose and can address the needs of a range of audiences across a range of purposes. These models require a modular approach to their design. Such a design will allow hybrid models to be developed that incorporate analytical, numerical and heuristic approaches in an over-arching framework. An example of such a framework is the E2 modelling environment and catchment modelling toolkit created by the e-water CRC. The major research providers in the GBR catchments (CSIRO and NRW) are both members of this CRC and there is much to gain for research in the GBR region from closer affiliation.

Workshop Overview and Objectives

Background

During the past two decades the export of sediment and nutrients from Great Barrier Reef (GBR) catchments has been estimated using a range of modelling techniques. Models applied to GBR catchments include SedNet, Annex, EMSS, E2, LISEM, and Savanna.au. Of these approaches, the one that has been applied most frequently and received the most attention, both from the modelling community, as well as the policy/decision making community is SedNet. It utilises spatially-distributed data to calculate a mean annual mass balance for an entire catchment as well as each river link within a drainage network.

The purpose of this workshop was to examine the strengths and weaknesses of the models which have been applied to GBR catchments, as well as to examine the tools that we currently have or may soon have in order to define the features of the ‘next generation’ of sediment and nutrient models which will be applied to GBR catchments over the coming years.

The workshop was based around the following questions and proposed outputs:

Setting the Scene

Aim: What are the current needs of decision makers, stakeholders and agencies for sediment and nutrient modelling in GBR catchments?

Output: A list of requirements for sediment and nutrient modelling.

The Past

Aim: Provide an overview of the sediment and nutrient modelling which has been carried out in GBR catchments to this point in time. ie. What has been done already?

Output: A review of sediment and nutrient models which have been applied to GBR catchments and a list of associated model assumptions.

The Present

Aim: Assess the current state of the art in sediment and nutrient modelling. ie. What tools do we have to improve our models?

Output: A list of the tools that we have at our disposal to improve our current models.

The Future

Aim: Based on past experience and present needs & abilities, what sort of models need to be developed and applied to the GBR catchments?

Output: A conceptual model of sediment and nutrient generation, cycling, transport and export in GBR catchments, and recommendations for future modelling approaches.

Summary of Outcomes

1. Setting the Scene: What do science, policy and management groups want from sediment and nutrient modelling approaches?

In preparation for the meeting, Mike Grundy (CSIRO Theme Leader) coordinated a consensus statement by a cross-section of science and policy leaders in catchment and water ecosystem management in Queensland and elsewhere to sediment and nutrient modellers (*Attachment 1*). The statement is a message to scientists working in sediment, nutrient and pesticide modelling relevant to the GBR Catchments. The statement is intended to stress the importance of this work, the need for a coherent and understood strategy, and to underline the level of support. It outlines the drivers for improved modelling, emphasises the need for coordination and strategic oversight, and identifies some of the key challenges to sediment and nutrient modelling in the GBR Catchments.

It is primarily agreed that there is a need for more strategic, coordinated and collaborative approach to modelling in the GBR which attempts to address system-wide issues (that is, which encompass linkages between catchments, estuaries, and the Reef). The models should be characterised by transparency, definition of uncertainty and communicability, and strive for the capacity to incorporate variability such as climate change, events and regional differences. Development and application of the models needs to be intertwined with users to ensure that the models are fit for purpose and can address the needs of a range of audiences across a range of purposes.

This session of the workshop provided an opportunity for representatives from science, policy and management groups to reiterate their needs related to the objectives of the workshop. The representatives were:

- Rachel Eberhard – Manager, Reef Water Quality Partnership (RWQP)
- Don Begbie – Director Natural Resource Sciences, Department of Natural Resources and Water (NRW)
- Bob Speirs – Director Environmental Sciences, Environmental Protection Agency (EPA)
- Scott Crawford – Operational Manager, Burdekin Dry Tropics NRM (BDTNRM)
- Colin Creighton – Executive Officer, Mackay Whitsunday NRM
- Nathan Johnston – Fitzroy Basin Association (FBA)
- Peter Wilson – National Land and Water Audit (NLWA)

A summary of each of the participants key needs are provided in *Attachment 2*.

The workshop participants responded to the presentations provided by the end user representatives with several issues requiring further clarification to enable them to respond to the end user needs:

- Mechanisms to progress from reactive, short term funding opportunities to strategic, longer term arrangements.
- Clear definition of the questions to be answered; what is needed, by when and for what purpose, including definition of the scale and precision that is required.
- Mechanisms to facilitate the dialogue about uncertainty and what level of uncertainty is acceptable to address particular issues.
- Strategies for filling data and information gaps; models to meet end user needs require best available knowledge of processes. Currently there is insufficient knowledge of how models represent systems, application of models at multiple scales, poor collection of supporting monitoring data, and little understanding of the trade offs between simplified and complex models.

These issues were agreed by the end user groups with some suggestions as to how they can be addressed. It was generally acknowledged that many of the outstanding issues are challenging to resolve and require a collaborative effort to progress resolution. Other key points of discussion:

- *Key modelling needs*:
    1. Sources of sediments, nutrients, contaminants;
    2. Capacity to influence discharges;

3. Ecosystem responses in the receiving environment;
4. Lag times;
5. A stronger link between land management practices and system response.

- *Socio economic aspects*: Social data inputs are challenging. We lack good mathematical algorithms to incorporate social sciences. It is important to include adoption mechanisms into the delivery of modelling results.
- *Uncertainty and scale required:* Regions will likely develop interim, refined and confirmed targets over a 10 year period. Need to work with modellers to develop targets and recognise scope for improvement (adaptive management framework).

The conclusion from this session was that all participants – end users and modellers - are interested in improving communication. Further exploration is required on how to manage change in our scientific information, and regularly revisit what is needed, what is possible and what are the best areas for investment.

2. The Past: Lessons learnt from sediment and nutrient modelling approaches applied to GBR catchments

This session considered lessons learnt from past sediment and nutrient modelling approaches applied in the GBR Catchments. A series of presentations outlined projects that utilised SedNet, ANNEX, EMSS and E2 modelling approaches, as follows:

- Overview – Lex Cogle (Session chair) - NRW
- EMSS and SedNet: Tim Ellis - CSIRO
- SedNet and E2: Ross Searle – NRW

The key points from the individual presentations are provided in *Attachment 3*.

An overview of some key examples were provided by Rebecca Bartley (Herbert and Douglas), Heather Hunter (Johnstone), Cameron Dougall (Fitzroy), and Banti Fentie (Burnett Mary). A Panel Discussion with each of the above presenters {Tim Ellis (CSIRO), Rebecca Bartley (CSIRO), Heather Hunter (NRW), Cameron Dougall (NRW), Banti Fentie (NRW) and Ross Searle (NRW)} provided an opportunity to discuss past projects and lessons learnt. The key points of discussion were:

- *Communication:* A number of examples were presented where local ownership and engagement in proposals led to a successful outcome. In contrast, where this was lacking, the process typically failed.
- *Complexity:* More complex models are not necessarily the solution to the problem. Adding complexity is pointless if the data does not exist to support this additional complexity.
- *Data availability:* There is a lack of supporting data in many GBR catchments. This will need to be addressed before real progress can be made.
- *Uncertainty:* There is a need to communicate uncertainty in model outputs to end users, but this needs to be communicated carefully and the expectations of the end users need to be managed right from the outset.
- *Long term approach:* There is a need for managers and policy makers to take a long term approach to both monitoring and modelling. Throwing a lot of money at a problem when you have a short time frame is not going to provide good outputs.

Summary of lessons learnt from past projects:

- **The importance of communication frameworks to support projects in terms of understanding how to engage clients (policy, science, regional groups) and accepting different paradigms of behaviour.**
- **The appropriate level of model complexity depends on the decision to be made.**

- **The usefulness of data sets varies greatly in terms of their validity and comprehensiveness.**
- **There is often a lack of knowledge of catchment behaviour.**
- **There are large challenges in moving across scales and quantifying uncertainty.**
- **Long-term funding is needed, as is a long-term strategy.**

3. Sediments: What system lags need to be taken into account in sediment modelling?

This session focussed on sediment modelling and specifically the system lags that need to be taken into account. A series of presentations outlined the key system lags that influence sediment modelling, as follows:

- Overview: David Post (Session chair) - CSIRO
- Modelling sediment delivery from hillslopes: Peter Kinnell – University of Canberra
- Delivery from paddocks: Hillslope erosion and sediment properties: Mark Silburn - NRW
- Riparian interception: Peter Hairsine - CSIRO
- Storage within stream systems, Burdekin catchment: Rebecca Bartley- CSIRO
- Dams as sediment traps: Brad Sherman - CSIRO
- Lags in sediment and nutrient export – the example of Fitzroy Estuary and Keppel Bay – a highly episodic system in dry tropical Australia: Phillip Ford - CSIRO

The key points of the individual presentations are provided in *Attachment 4*.

A Panel Discussion with each of the above presenters {David Post (CSIRO), Peter Kinnell (University of Canberra), Mark Silburn (NRW), Peter Hairsine (CSIRO), Rebecca Bartley (CSIRO), Brad Sherman (CSIRO) and Phillip Ford (CSIRO)} provided an opportunity to discuss the main system lags that influence sediment modelling. Key points of discussion:

- *Need for improved system understanding:*
  - The driving hydrological processes are not well represented, eg rainfall-runoff relationships. This can be improved through improved rainfall measurements.
  - Issues of scale – process and response are different at different scales.
  - Temporal (event) dynamics in hydrology.
  - Current models typically do not include a 'reaction time' to specific changes, ie. we are often lacking information about what has happened at each point in time.
  - There is often little linking between hillslope processes and in-stream dynamics – deposition etc.
  - Riparian zones impact ambient conditions but may have limited or no impact on big events.
  - Are sediment fractions important? Bedload versus suspended, different time scales – are we interested in coarse sediments in GBR catchments?
  - Temporary storage and remobilisation of sediment in river networks can considerably modify the downstream delivery of a sediment pulse and there are insufficient data for catchment models to represent these processes. Time-stepping models that don't represent these processes may not properly represent the temporal patterns of downstream delivery.
  - We often don't need both spatial and temporal patterns in the one model; use the appropriate modelling methods depending on the problem to be solved rather than trying to build one super-model.
  - Address the capacity of dams and floodplains to provide storages in the system.
  - What is the efficacy of remediation and are we measuring it? eg. Farm dams, riparian buffers.
  - Deposition in dams approach is based on mean annual discharge – CSIRO projects (Post and Henderson) show that the Burdekin River can fill the Burdekin Falls Dam with water from one day's discharge in most years. Requires investigation of the impact of dam trapping where annual flow is delivered in very short timeframes. Trapping efficiency needs to be integrated over time.

- Concerns regarding re-suspension of stored nutrients plus new nutrients in estuarine and coastal environments.
- Research from small geographic areas needs to be used to infer the response of large areas, eg. Don't know grazing pressures across the whole Burdekin catchment. Use of remote sensing could help here.

- *Data availability:*
  - The landscape of the GBR catchments is generally poorly characterised eg. rainfall, soils, cattle densities.
  - Rainfall measurements are sparse.
  - Modelling requires established hydrology and erosion data, however due to limitations of time and funding these are rarely measured.
  - Sediment budgets are the main tools – tracer budgets and long term measurements of sediment deposition are needed.

- *Communication:*
  - Community engagement – how to represent outputs in an understandable yet scientifically rigorous way.
  - Dialogue between land users and modellers is required to inform the land users and to assist the modellers represent the system.

Summary of system lags and sediment modelling session:

- **The importance of improved system understanding, including the driving hydrological processes, temporal variations, sediment fractions, the function of riparian vegetation in events, the role of dams and floodplains as sediment traps, and the potential impacts of sediment re-suspension.**
- **Limited data availability and information at various spatial and temporal scales limits our ability to test and improve models.**
- **The importance of communicating our understanding of system lags and the limitations they may place on model outcomes to clients.**

4. Nutrients: What processes are we missing in our nutrient modelling?

This session focussed on nutrient modelling and specifically, key information gaps that need to be taken into account when assessing modelling approaches. A series of presentations outlined the key processes that influence nutrient modelling, as follows:

- Overview – Brad Sherman (Session chair) - CSIRO
- The role of groundwater: Keith Bristow - CSIRO
- In-soil transformation: John Armour - NRW
- Riparian zone denitrification: Heather Hunter - NRW

The key points of the individual presentations are provided in *Attachment 5*.

A Panel Discussion with each of the above presenters {Brad Sherman (CSIRO), Keith Bristow (CSIRO), John Armour (NRW), Heather Hunter (NRW)} provided an opportunity to discuss the main processes that influence nutrient modelling. Key points of discussion:

- *Need for improved system understanding:*
  - Reiterated many of the points highlighted in the system lags discussion above.
  - Nutrient speciation is important because of the bio-availability of different nutrient species..
  - Missing fundamental understanding of the mass balance of nutrients.
  - Still limited knowledge of nitrogen dynamics with complexity of drivers, eg. dissolved organic carbon, iron availability.

– The overall aim is to take the lessons learnt from fieldwork and put them into models, however there is currently insufficient understanding of the system to be able to define model inputs.
– There is a lack of differentiation between land uses and soil types, and thus a limited empirical database to be able to calculate event mean concentrations (EMCs); especially dissolved/bio-available forms.
– There is a lack of modelling of in-soil processes, as well as the processes for nutrient generation on degraded lands.
– There is a need for better understanding of the hydrological cycle and pathways to the reef..
– Which pathways are important, in which regions, scales and land uses? Microbiological processes are unknown.
– Groundwater flow is poorly understood, ie. Where does it occur and what are the rates of flow/discharge.
– How effective are riparian zones? Especially in trapping particulate versus dissolved nutrients?

- *Data inputs:*
  – There is uncertainty related to the nutrient concentrations in the input data – eg. Fitzroy – no spatial pattern to errors; average of measured values were 80% higher than values from ASRIS database.
  – Detail and scale – high powered research investigations versus management models – can we simplify?
  – Continuity of "right" monitoring to measure inputs as well as trace the movement and concentration of nutrients.

- *Management Responses:*
  – Lack of understanding of nutrient behaviour in GBR catchments does not mean we should not progress investment opportunities; the cost of not doing something now will defer costs to later generations. Modelling is useful to facilitate understanding of the consequences in the short and long term.
  – Relatively simple solutions are desirable, eg. planting riparian vegetation.
  – How much work and resources would be needed to answer the questions related to nutrient behaviour and pathways to the reef?
  – Nutrient modelling is required across a range of scales, eg. need detail to provide feedback to growers – simple correlations on needs and manageable losses.
  – Further investigation is required of the potential of using salinity models as a surrogate for nitrate modelling.

Summary of nutrient modelling session:

- **Importance of improved system understanding, including those highlighted for system lags and lack of differentiation between land uses and soil types and nutrient behaviour (especially dissolved/bioavailable forms), identifying which pathways are important, nutrient speciation and influences and in-soil processes.**
- **There is limited data availability and information at various spatial and temporal scales.**
- **Need for better understanding of the effectiveness of management actions in relation to nutrient management and the role of modelling.**
- **Influencing the direction of management responses and acting on available information in an adaptive management framework.**
- **Importance of communication of our understanding of nutrient processes and the limitations they may place on model outcomes.**

5. Agreed challenges for sediment and nutrient modelling

From the presentations and discussions of the sessions on the limitations of current sediment and nutrient modelling capacity (outlined above), the workshop participants listed the key challenges. These are included in *Attachment 6*. The following key challenges were agreed by workshop participants:

1. Sediment dynamics
2. Hydrology
3. Nutrients
4. Scaling
5. Data
6. Uncertainty
7. Links to management and policy

6. Suggestions for the way forward

The workshop then broke into small groups to tackle the key challenges outlined for sediment and nutrient modelling in GBR catchments. Each group was instructed to address the user needs in relation to the issue, identify the specific challenges to meeting those needs and offer suggestions for the way forward. The responses from each group are included in *Attachment 7* and summarised below.

1. *Sediment dynamics:* Need to work on the delivery of sediment from hillslopes, incorporate a temporal signal into gully erosion, and determine system lag times in both the channels and in dams.
2. *Hydrology:* Need to move from long term average behaviour to event based approaches, incorporate linkages between surface and groundwater, and capture the temporal dynamics of the hydrologic response.
3. *Nutrients:* Need to move from consideration of total N and P to the speciation of nutrients, and need to relate landuse practices to nutrient concentrations and loads.
4. *Scaling:* Need to improve our representation of landscape processes at a finer spatial resolution, look further at the interfaces between processes, and incorporate event based information into our models.
5. *Data:* Need to characterise the landscape better using remote sensing, capture variability in monitored data, and monitor over longer time periods.
6. *Uncertainty:* Need to have quantitative measures of uncertainty incorporated into model results, as well as representing this uncertainty in a way that is understandable to the end users of the information.
7. *Links to management and policy:* Need to develop a long-term strategic approach towards the development of models, ensure more effective communication between modellers and end users, and incorporate the effect of land management changes into the models.

7. Tools: What tools do we have to improve our modelling approaches?

This session focussed on the tools available to improve sediment and nutrient modelling approaches. A series of presentations outlined the range of tools currently available, as follows:

- Overview – Rebecca Bartley (Session chair) - CSIRO
- Uncertainty in SedNet: Petra Kuhnert - CSIRO
- E-water uncertainty project: Scott Wilkinson - CSIRO
- Loads tool and parameter library: Nick Marsh - EPA
- Remote sensing of groundcover: Peter Scarth - NRW

The key points of these presentations are provided in *Attachment 8* and are summarised below:

- *Representation of uncertainty:*
  - There are a number of approaches available to incorporate uncertainty into sediment and nutrient models. These include Bayesian approaches such as BACCO and Monte Carlo runs to estimate parameter uncertainty.
  - The uncertainties generated also need to be propagated through the model – some uncertainties grow as they are propagated through the system while others act to cancel each other out.
  - The issue of how to quantify uncertainty is still up in the air. The approach taken depends on the issues to be considered.
  - How to present uncertainties to the client or end user of the information is also a very open question. We need an approach that is robust, but which also conveys the information in an easy to understand way for the non-expert.

- *Loads tool and parameter library*
  - Many different approaches exist for determining the sediment load of catchments based on irregular sampling of suspended sediment, and the predicted loads vary depending which approach was used. The loads tool allows an easy comparison of these approaches.
  - The parameter library, also developed by NRW, may be a useful technique for comparing the parameters of and calibrating sediment and nutrient models.

- *Remote sensing of groundcover*
  - Tools have been developed at NRW to calculate bare ground indices and foliage projective cover from Landsat images.
  - These tools currently only work up to a foliage projective cover of 20% but work is underway to increase this.
  - Work is also underway to extend this approach to MODIS imagery which will provide a much higher temporal resolution (16 days compared to 1 year for Landsat).

At the conclusion of this session, the individual groups reconvened to start to define the tools that could be used to fill the key information gaps identified in the previous break-out session. The following session attempted to synthesise these issues to identify the desired characteristics of a sediment and nutrient model for the GBR region.

8. Synthesis: What are the desired characteristics of a sediment and nutrient model?

This session commenced synthesis of the discussion in an attempt to develop a cohesive view of the desired characteristics of a sediment and nutrient model for the GBR. An overview of the issue and presentation of an example of an existing framework, E2, was provided as follows:

- Overview – Freeman Cook (Session Chair) - CSIRO
- E2 and catchment modelling toolkit: Geoff Podger - CSIRO

The key points of these presentations are provided in *Attachment 9*.

A Panel Discussion involving Freeman Cook (CSIRO), Geoff Podger (CSIRO), Ross Searle (NRW) and Tim Ellis (CSIRO) provided an opportunity to discuss the preferred approaches to sediment and nutrient modelling. Key points of discussion:

- *E2 - Access to products and input to product development*
  - It is important to develop usable products; as a result we need to determine how to share access to codes and model updates.
  - Important that people writing software understand user needs. Makes sense to use software engineers, but they often do not understand the system being modelled. Suggest engaging software engineers upfront to incorporate new data into the framework; scientists write own code so other people can share it.

- Need to have a common place for both models and data. Need to make data as well as models more accessible. Various data collection and storage systems are currently being developed and investigated, eg. potentially WRON.
- Can insert functionality of SedNet into E2 to build applications. Recognise ongoing need.

- *E2 - Communication and adoption*
  - Lack of communication has hindered use of E2 as a catchment modelling tool.
  - E2 is historically largely southern based, resulting in widespread SedNet application in the north. Acknowledged issues with placing products on website at end of development – varies with what is used and what received further funding. Will look at the e-water *Toolkit* being a national repository for future tools.
  - Strategy for adoption and training - in past used 'development' project to beta test tools. E2 will use similar approach that requires supporting documentation and training.
  - E2 has not been well adopted; need to be expert modeller to use it – flexible but very complex. E-Water will attempt to address this issue through interfaces with end users.
  - How do we make the linkage to GBR research and roll out E2 to the GBR? Partners of E-Water (including CSIRO, NRW) have access to all products. Linkages difficult as the models run on different time steps.

The existing E2 framework is available to researchers (particularly NRW and CSIRO) working in GBR catchments. There are however some issues relating to the uptake of E2:

- **Developing mechanisms and systems to allow and promote access to the *Toolkit* products.**
- **Demonstrated need for users (other than scientists and managers) to provide input to product development.**
- **Necessity of a common portal for storage of models, tools and data.**
- **Importance of communication throughout product development and facilitation of adoption.**

9. Where to from here: How will we achieve the desired goals?

The final session of the workshop aimed to draw the focus of the workshop back to the end user needs, and to discuss how to achieve the desired goals. It was agreed that the key issue for the way forward for sediment and nutrient modelling in the GBR region is better coordination of effort and resources. Peter Hairsine, CSIRO, reiterated these issues as the Session Chair, summarised below.

Continued work to improve target setting using an "adaptive management " approach:

- Water quality monitoring – where:
  - End of catchment a priority?
  - Hot spots – validation via local knowledge, data and research to confirm model outputs?
  - Downstream of investment sites? (but very long term); What is long term?
- Water quality monitoring – other aspects:
  - Database and interpretation issues
  - Groundwater
  - Tracer studies
- Management practices evaluation - need more information on impact of management practices, eg. delivery ratios.
- Landuse updates - ensure land use updates are used in interpreting water quality changes.
- Improved modelling:
  - Model is available for continued interrogation.
  - Model platforms (other than SedNet) are currently available for use.
  - E-Water has clear niche for tool development – most participant agencies are a member.

Key achievements in sediment and nutrient modelling:

- Responding to Reef Plan requirements.
- Capacity building - expertise in Dept, underlying process explanation, postgraduate opportunities, increased teamwork across organisations eg CSIRO / NRW.
- Policy or investment decisions - RIS, Strategic Fund, National Water Fund, other projects eg. AGO.
- Stakeholder understanding/awareness of the applications of models - presentations to boards, IAG's, board staff, facilitated meetings of technical panels, scenario analysis.

A Panel Discussion inviting back the representatives of the user groups facilitated discussion of the significant issues for coordination, including examples of successful experiences from their organisations perspective. The Panel included Lex Cogle (NRW), Mike Grundy (CSIRO), Rachel Eberhard (Reef Water Quality Partnership), and Scott Crawford (Burdekin Dry Tropics NRM). The discussion is outlined in *Attachment 10*, and summarised below.

Key components of for successful future coordination:

- **Securing high level support.**
- **Multi-agency effort (no single lead agency) and multidisciplinary teams.**
- **Communication planning and strategy.**
- **Capacity building – of modellers and users (eg. training to commission modelling work).**
- **Establishing appropriate frameworks for applying modelling outcomes.**
- **Management of expectations; realistic deliverables.**
- **Accepting failures and identifying opportunities for growth.**
- **Opportunities for collaboration between Moreton Bay Partnership and Reef Water Quality Partnership; compelling case to promote funding and commitment.**

A final action list of tasks to consolidate collaboration was agreed by workshop participants:

Tasks	Who	By When
Data sharing agreements. Formal and informal	CSIRO, EPA, NRW	July 2007
Develop specific multi-organisational project to determine groundwater interaction with receiving water bodies	John Armour Keith Bristow	June 2008
Early engagement with relevant stakeholders, eg. Regional groups to facilitate collaboration	Depends on project	Depends on project
Status of knowledge and activity within and between regions; online site?	eg. Australian Natural Resources Online?	
Coordinate managers	RWQP	June 2008
Coordinate scientists (eg. E-Water, CSIRO, NRW) – need key focus projects and identify team?	Depends on project	Depends on project
Coordination between scientists and managers	RWQP SAP starting point	June 2008
Annual forum	NRW	Annually
CSIRO and RWQP collaboration	CSIRO, RWQP	June 2008
Coordination, collection, sharing and publishing of data	WRON, NLWRA, NRW, CSIRO	2008
Follow up from this meeting to flesh out debate issues raised and encourage dialogue between end users and modellers	WfHC, NRW, end users	2007+
Agreed set of terms of governance for IP, roles and responsibilities of data sharing	All willing	2007+
Develop operational plan following from governance agreement	All willing	6 months agreed governance
Resourcing to implement operational plan	All willing	6 months agreed governance

10. Conclusions and Evaluation

At the conclusion of the workshop, participants reiterated the importance of follow up of the actions identified for the way forward and requested circulation of the outcomes of the workshop. This document represents that outcome.

This document will be distributed to all workshop attendees, catchment management groups, policy and decision makers in GBR catchments. It is hoped that this will provide these groups an understanding of the current state-of-the-art in sediment and nutrient modelling (as of November 2006), and will provide an impetus for the agreed future modelling approaches to be implemented by the lead organisations (CSIRO and NRW).

List of Attendees

1. John Armour, NRW Mareeba
2. Rebecca Bartley, CLW Brisbane
3. John Bennett, EPA Brisbane
4. Naidu Bodapati, NRW Brisbane
5. Keith Bristow, CLW Townsville
6. Ken Brook, NRW Brisbane
7. Brian Bycroft, NRW Brisbane (proxy for Peter Gilbey)
8. Chris Carroll, NRW Rockhampton
9. Chris Chilcott, DPIF Charters Towers
10. Lex Cogle, NRW Mareeba
11. Freeman Cook, CLW Brisbane
12. Perran Cook, CLW Brisbane
13. Scott Crawford, Operations Manager, BDTNRM
14. Ian Dight, BDTNRM Townsville
15. Cameron Dougall, NRW Rockhampton
16. Rachel Eberhard, Reef Water Quality Partnership, Brisbane
17. Tim Ellis, CLW Canberra
18. Robin Ellis, NRW, Bundaberg
19. Grant Fraser, NRW, Brisbane
20. Banti Fentie, NRW Brisbane
21. Phillip Ford, CLW Canberra
22. David Freebairn, NRW Toowoomba
23. Mike Grundy, WfHC Brisbane
24. Peter Hairsine, CLW Canberra
25. Mick Hartcher, CLW Townsville
26. Robert Hassett, NRW Brisbane
27. Louise Hateley, NRW Mareeba
28. Aaron Hawdon, CLW Townsville
29. David Haynes, GBRMPA
30. Anne Henderson, CLW Townsville
31. Carol Honchin, GBRMPA
32. Heather Hunter, NRW Brisbane
33. Nathan Johnston, FBA
34. Peter Kinnell, University of Canberra, Canberra
35. Petra Kuhnert, CMIS Brisbane
36. Adam Liedloff, CSE Darwin
37. Mary Maher, Facilitator, Mary Maher & Associates
38. Nick Marsh, EPA Brisbane
39. David McJannet, CLW Brisbane (Wednesday only)
40. Lachlan Newham, ANU Canberra
41. Bob Noble, NRW Rockhampton
42. Jean-Michael Perraud, CLW Canberra
43. Geoff Podger, CLW Canberra
44. David Post, CLW Townsville
45. Arthur Read, CLW Canberra
46. Ken Rohde, NRW Mackay
47. Peter Scarth, NRW Brisbane
48. Ross Searle, NRW Brisbane
49. Brad Sherman, CLW Canberra
50. Mark Silburn, NRW Toowoomba
51. Grant Stone, NRW, Brisbane
52. Kirsten Verburg, CLW Canberra
53. Jane Waterhouse, WfHC Townsville
54. Dave Waters, NRW Toowoomba

55. Tony Weber, WBM Brisbane
56. Scott Wilkinson, CLW Canberra

Additional Science, Policy and Management representatives attending Session 1: Setting the Scene

1. Don Begbie, NRW Brisbane
2. Geoff Borschman, Department of Premiers and Cabinet
3. Chris Chinn, Reef Water Quality Partnership
4. Colin Creighton, Mackay Whitsunday NRM
5. Louise Matthieson, CSIRO
6. Bob Speirs, EPA Brisbane
7. Peter Wilson, National Land and Water Audit

Apologies: Unable to attend

1. Brett Abbott, CSE Townsville
2. Noel Ainsworth, SEQ Catchments
3. Rob Argent, Melbourne University
4. Garry Bastin, CSE Alice Springs
5. Mike Berwick, Mayor, Douglas Shire, Cairns
6. Jon Brodie, ACTFR Townsville
7. Guy Byrne, CLW Canberra
8. John Carter, NRW
9. Jeff Corfield, CSE Townsville
10. Barry Croke, ANU Canberra
11. Jacky Croke, ADFA Canberra
12. Alan Dale, CEO, FNQNRM
13. Graeme Esslemont, NRW
14. Miles Furnas, AIMS Townsville
15. Peter Gilbey, NRW, Brisbane
16. Rodger Grayson, Melbourne
17. Beverly Henry, NRW Brisbane
18. Alex Herr, CSE Townsville
19. Michael Herring, NRW Rockhampton
20. John Ludwig, CSE Atherton
21. Tim Lynham, CSE Townsville
22. Greg McKeon, NRW
23. Lucy McKergow, University of Otago, NZ
24. Jerry Miller, Western Carolina University, USA
25. Brigid Nelson, DPIF Charters Towers
26. Jon Olley, CLW Canberra (Thursday only)
27. Bob Packett, NRW Rockhampton
28. Tim Pietsch, CLW Canberra
29. Velupillai Rasiah, NRW Mareeba
30. Dan Rattray, QDPIF Toowoomba
31. Joe Scanlan, NRW
32. Matt Stenson, CLW Brisbane
33. Andy Steven, CLW Brisbane
34. Helen Wahn, Department of Premiers and Cabinet

Reviewer

Jim Wallace, CLW Townsville

The Past, Present and Future of Sediment and Nutrient Modelling in GBR Catchments

Workshop Attachments

Attachment 1: Statement by science and policy leaders to sediment and nutrient modellers – November 2006

This is a statement delivered by a cross-section of science and policy leaders in catchment and water ecosystem management in Queensland and elsewhere. It is a message to scientists working in sediment, nutrient and pesticide modelling many of whom are meeting to discuss the past, present and future of this modelling in GBR catchments and the links with similar work in the Great Barrier Reef. It is intended to stress the importance of this work, the need for a coherent and understood strategy and to underline the level of support.

The drivers for improved modelling
Effective research into and delivery of catchment sediment and nutrient modelling is of increasing importance in Queensland. The generation, transport, storage and impact of sediments and nutrients is a complex and disputed area – and the need for a coherent and transparent strategy for modelling is recognised by planners, policymakers, governments and the scientific institutions. There are clear, specific drivers in geographic areas as well; especially in reef catchments and the reef itself, in the streams of South-east Queensland and in Moreton Bay, in many of our regional body areas, in near-shore fisheries and in a number of specific impacted areas. The water quality issue is also increasingly intertwined with the issues around ensuring adequate water supply and quality for urban and agricultural use and for environmental purposes. We have moved beyond questioning the need for this science and modelling – now the focus and demand is for effective, strategic modelling.

Progress in strategic modelling in Queensland in response to these issues is also likely to have national application (eg work being undertaken by the National Water Commission and subsequently by the Audit under the National Monitoring and Evaluation Framework and in the development of the National Water Quality Model).

The need for coordination and strategic oversight
The recent "GBR Catchments modelling project conducted by the Queensland State agencies (NRW and EPA) and CSIRO demonstrated that there is a clear interest in moving beyond a "bits and pieces" approach to a broadly agreed strategy delivered from across the scientific community to policy and planning clients including the national and state government, CSIRO, Reef organisations and Regional Bodies. An effective modelling strategy will be widely understood and communicated, will define the utility of existing modelling and provide a roadmap to improving models and predictions. This will then more effectively guide investment, support monitoring, assess progress and lead to better policies and plans. It is also more likely to produce a sustained investment in the modelling itself.

The challenges involved
Achieving a strategic approach to sediment and nutrient modelling provides challenges to science leaders, as well as policymakers and planners, and to you as the community of sediment and nutrient modellers working in Queensland.

1. The challenge to us is to clearly enunciate the science questions that are being asked and to provide coordinated funding, direction and feedback. We need to clearly identify what has or has not worked in meeting these complex needs, determine what is needed in the future and to provide the environment to support development. We also need to provide the policy / institutional framework for model development, testing and accreditation.
2. The challenge to you is to:
   a) to understand the science questions that are being asked by the policy makers and planners;
   b) define the best ways to use the models, model runs and predictions which we currently have;
   c) develop an agreed modelling framework for the short to medium term for consistent application and assessment of model outputs;
   d) identify and communicate the potential improvements in performance, certainty, utility, calibration and integration which science may provide over time;
   e) define the choices / trajectories available to us to get there; and

f) identify where the relative strengths exist across the science providers and the means for collaboration and cooperation.

Specific challenges
We recognise that this is a sediment and nutrient modelling workshop. This is a crucial part of our information needs but is a component in a bigger system. So, at this or in subsequent meetings, we also request that you use this opportunity to:

- identify the modelling and science linkages which will make it possible to connect catchment change to outcomes in reefs, water bodies, wetlands and other receiving environments;
- link modelling with monitoring, both in terms of validating the models so that results are above dispute and to feedback to monitoring programs improvements in the nature of data collected, its analysis, reporting and the management actions that follow from this analysis;
- discuss ways to use sediment and nutrient modelling to prioritise investment in on-ground action aimed at specific ecosystem protection or restoration;
- identify the modelling challenges in better understanding nutrients throughout the total water system in more specific detail (including bio-availability);
- develop models for chemicals and pollutants in terms of quantity, transport, impact on receiving ecosystems and improved practice implications;
- identify existing or required links with other models, both biophysical (eg. marine) and socio-economic;
- identify issues of certainty, variability, lags and buffering both in terms of the modelling required and in how these might be communicated through water quality targets and apparent changes to the resource; and
- capture benefits from existing model development platforms (especially the TIME and Catchment modelling toolkit) that supports the collaborative development of sediment and nutrient models.

Interaction
Some of us will attend the first session of the workshop so that we can discuss these and related issues; we are all available more generally to work on achieving better use of sediment and nutrient modelling in our environmental management.

Statement developed and endorsed by:
Qld Government / Qld organisations:

NR&W:	John Mullins A/ED NRSc
DPI&F:	Beth Woods ED R&D Strategy
EPA:	Bob Speirs ED Environmental Sciences
GBRMPA	Hugh Yorkston, A/ED

Commonwealth Government / National organisations:

Bureau Rural Sciences	Colin Grant ED
NLWR Audit	Blair Wood Director
CSIRO	Jon Olley, Program Leader CLW
CSIRO	Mike Grundy, Theme Leader, GBR
eWater	Peter Wallbrink, Executive Manager Research & Education

Regional NRM Management:

Regional Groups Collective:	Andrew Drysdale, EO
FNQNRM:	Allan Dale, CEO
Burdekin Dry Tropics:	Scott Crawford, Operations Manager
Mackay-Whitsunday:	Col Creighton, CEO
Burnett-Mary:	Carolyn Taylor, A/CEO
Fitzroy Basin Assoc:	Clair Rodgers, A/CEO
SEQ Catchments	Simon Warner, CEO

Reef Partnership:	Rachel Eberhard, Program Manager

Attachment 2: Summary of user needs presented at the workshop

Colin Creighton – EO, MWNRM

1. Need a stronger link to land management practices and how to foster better practice.
2. Systems approach is required for whole of catchments, from ridges to reefs.
3. Monitoring, modelling and mapping – combine and coordinate. Demonstrate uncertainty, accuracy.
4. Other transport systems: nutrients. Need for all pathways for and chemicals, vectors, their mobility, impacts, bioaccumulation to be assessed and the way to put this knowledge back to practice.
5. Lag times, expectations, resilience, thresholds need to be incorporated.

Scott Crawford – Operational Manager, BDTNRM

- Reinforce Colin's views.
- Key need – what are the management practices and interventions required to meet targets. Where, when and what interventions to apply.
- How – differences between what policy makers *want* and what they *need*. Focus on the model output, forget detailed specifications for users, level of expertise, acceptable levels of uncertainty, timeframes, data requirements, costs.
- Develop models in a collaborative framework – participative process.
- Measures of success will be the level of adoption.

Bob Speirs – Director Environmental Sciences, EPA

- Rigour and confidence behind decisions.
- Variance between years and systems.
- Climate change big issue.
- Health of natural systems throughout Qld. Focused on stressors, resilience.
- How we understand complexities and where to intervene through best management practices (BMP), regulation or other.
- Interested in way models give rigorous basis for decision making.
- Understanding assimilative capacity, influence of events, cumulative contributions.
- Heading towards load based licensing.
- Link to landuse practices and consider diffuse sources of pollutants.

Don Begbie – Director Natural Resource Sciences, NRW

- Clear definition of the questions and answers required. Make sure we are answering the questions being asked, and not some other question.
- Models fit for purpose.
- Basic agreement on framework for the future. Consistency between approaches in short to medium term – comparable.
- Links to best practice. Forecast scenarios – what difference does it make. Assessment of current practices, impact and success.

Rachel Eberhard – Manager, Reef Water Quality Partnership

- Refer to handout provided by the RWQP (Attachment 2.1). Note that RWQP also interested in receiving environment.
- Linkages (systems thinking) – land management, WQ to GBR health; across scales.
- Transparency, uncertainty and communicability. Development and application of model intertwined with users.
- Variability – climate change, events, regional.
- Usability – tools for managers. Range of audiences across a range of purposes. Complexity not always the answer.

Nathan Johnston – FBA

- *Relevance*. Assistance in planning and investment.

- *Linkages*. Multiple approaches – unique purposes. Need to spend time not thinking about how capacity of various approaches and how they can be linked eg. Catchment, receiving waters, asset assessments. How do the different types of models link to tell the whole of system story.
- FBA worked with 280 landholders in 2005/06 – need to understand how to improve actions, and quantify reductions and effects on GBR.

Peter Wilson – NLWA

- Where to invest – best bang for buck. Indicator framework to establish priority areas for research and investment.
- National implications – transferability, consistency. Integration of issues – physical, socio-economic.
- Specific data and information needs to establish models, complexity of models

Attachment 2.1: Reef Water Quality Partnership: Modeling Needs, November 2006

Background

The Reef Water Quality Partnership (RWQP) formalises ongoing collaboration between Australian and Queensland Government agencies and regional natural resource management bodies of the Great Barrier Reef Catchments[1], to support the Reef Water Quality Protection Plan (Reef Plan). The RWQP:

- Coordinates and evaluates water quality monitoring activities.
- Implements work plans and programs to deliver priority water quality activities.
- Supports improved land use planning and the adoption of sustainable production systems.
- Facilitates the development of water quality targets that link catchment management with the health of the Great Barrier Reef.

The purpose of this paper is to outline the needs of the members of the RWQP for modeling in the Great Barrier Reef (GBR) and it's Catchments.

RWQP scope

The scope of the RWQP is the GBR Catchments (including 5 Regional NRM regions) and the receiving waters of the GBR (ie. Catchment to reef). A critical gap in understanding the catchment to reef processes is the integration of catchment and receiving water processes, likely to be achieved by modeling across the freshwater, estuarine and marine interfaces.

The Regional NRM groups and the Queensland Government also have a strong interest in instream health and threats, however this is currently not within the focus of the RWQP at this time.

The priority contaminants of concern are suspended sediments, nutrients (N & P, N0X as a priority) and pesticides. The priority catchment areas are those currently supported by the Coastal Catchment Initiatives program to develop Water Quality Improvement Plans, ie. Douglas, Tully, Burdekin, Townsville-Thuringowa, Fitzroy, Mackay-Whitsunday catchments and Burnett.

Purpose of modelling

The RWQP requires modelling framework/s based on the best-available science, for quantifying:

- concentrations and loads of sediment and nutrients in catchments and receiving waters and trends with time;
- ecological effects of sediment and nutrients in receiving waters; and
- influences of changes in land use, land management, climate, etc on the above, at spatial and temporal scales relevant to management.

Outputs from modeling are required to support:

- target-setting processes;
- evaluation of progress against targets;
- analysis and integration of monitoring data and monitoring program design; and
- overall evaluation of Reef Plan performance.

Current status and emerging priorities

[1] The Great Barrier Reef Marine Park Authority (GBRMPA), the Department of Environment and Heritage (DEH), the Department of Agriculture, Fisheries and Forestry (DAFF), the Queensland Departments of: the Premier and Cabinet (DPC); Natural Resources and Water (NRW); Primary Industries and Fisheries (DPI&F); and the Environmental Protection Agency (EPA), and the regional natural resource management bodies: Far North Queensland Natural Resource Management (FNQNRM); Burdekin Dry Tropics Natural Resource Management (BDTNRM); Fitzroy Basin Association (FBA); Mackay Whitsunday Natural Resource Management (MWNRM); and the Burnett-Mary Regional Group for Natural Resource Management (BMRGNRM).

In summary:

- All regions (major catchments) have access to SedNet and ANNEX with scenarios generated through the Short Term Modeling project.
- Some regions have utilised EMSS as well (Fitzroy, Douglas), and Mike21 for Tully floodplain (CSIRO). Other models eg. Perfect and APSIM have been applied at different scales.
- All regions are investing in refining existing catchment models for immediate needs (required as part of the WQIP, mostly before June 2007).
- The Regional groups have expressed concerns and identified priorities in the current capacity of SedNet/ANNEX, including:
  - the role of water storages
  - modelling floodplains
  - accounting for coastal areas that drain directly to the marine areas
  - better representation of water quality effects associated with management interventions
  - better process modelling for nutrients
  - dynamic modelling of processes rather than long-term average values
- There is a need for increased emphasis on what specific input data will be required to facilitate the development and calibration of these future models (i.e. guiding future monitoring program development.
- There needs to be a concerted effort made into the determination of the level of certainty in the predictions made by these models with an associated sensitivity analysis presented in order to provide decision makers with an estimate of risk associated with decisions made.
- Receiving water and estuarine models for tropical Queensland are identified as a knowledge gap, and linkages to these models from catchments and estuaries are uncertain. Devlin et al., exposure model is being updated GBR-wide. King and Wooldridge hydrodynamic and nutrient-chlorophyll models used for Burdekin and Tully. Estuaries are not being effectively addressed (except Fitzroy).
- The Great Barrier Reef Marine Park Authority has established draft water quality objectives and associated ecosystem health guidelines to provide ecosystem specific trigger concentrations (or loads) of the key physico-chemical parameters where levels above or below pose a risk that adverse biological effects will occur. This information has been prepared as part of the development of Water Quality Improvement Plans in the GBR Catchment and will be an important component for developing effective water quality targets.
- A recent review by Prof. Rodger Grayson has identified issues and priorities for model development to support data assessment from load-based monitoring programs (Reef Plan Actions I5, I6), including recommendations to:
  - implement eWater CRC's E2 model as the preferred catchment modeling framework in the short-term;
  - in collaboration with eWater CRC progressively enhance E2 and its successor, WaterCAST, to better suit RWQP's needs;
  - develop strategies and priorities for addressing other model development requirements that are not within scope (or timeframe) for eWater CRC; and
  - as a matter of urgency review database needs and develop and implement a strategy for database development and data access, agreed by all parties.
- Regions will set initial water quality (load) targets for sediments and nutrients in 2007 based on modeled average annual loads (Sednet/ANNEX outputs) and available receiving water information (principally the updated exposure model and GBR guideline values).
- Pesticides remain a priority issue of concern with limited supporting data or tools (possibility of developing risk assessment models).
- NRW has initiated a 3-stage program to; 1) review the current state of knowledge concerning pesticides in the GBR region; 2) conduct an ecological risk assessment concerning pesticide residues in the GBR region; 3) design and implement an appropriate monitoring program for

pesticide residues in the region. Stage 1 commenced in October 2006; stages 2 and 3 to follow in 2007, subject to funding.

- The RWQP and others are progressing a more rigorous and consistent approach to evaluating the effectiveness of management practices for water quality, benchmarking and monitoring change. Industry will be a key partner in this work. Modelling tools will need to be responsive to these increasing demands for specific scenarios in a more complex landscape.
- Social and economic modeling is poorly developed. Peter Roebeling's work in the Tully is one example. There is a lot of interest in these prospective tools.
- Prioritising investments requires the consideration of tradeoffs between different scenarios and outcomes. It is envisaged that environmental metrics will be developed and utilised.
- Custodians are being established in the regions for future modelling runs. This expertise needs to be maintained by appropriate utilisation of the models and training where necessary.

Future vision

A GBR modeling strategy would:

- Aim to build a coherent and connected picture of the transport of key pollutants (notably nutrients, sediment and pesticides) to the GBR encompassing river catchments, estuaries, the inshore marine environment and GBR receiving waters.
- Identify a suite of tools available, data requirements and their appropriate uses.
- Establish appropriate custodianship of the databases and models.
- Provide a consistent approach across regions and over time that would allow:
    - regions to build skills and confidence in using model outputs;
    - experiences to be shared (technical, management etc) across regions and over time; and
    - provide information that can be summarised across regions.
- Not constrain Regions in their choices, but support and inform their choices.
- Provide a transparent framework that acknowledges and communicates constraints and uncertainties.
- Support a co-learning environment where technicians and 'end-users' participate in action research partnerships.
- Provide tools that assist to define and report water quality targets (concentrations and loads) in a way that accounts for flow variability, spatial variability in rainfall, land condition, antecedent conditions etc. These targets will be informed by a greater quantitative understanding of the linkages from land management practices (and management action targets) to water quality in rivers to impacts on marine ecosystems.

This workshop can help inform the development of such a strategy.

Attachment 3: Overview of Presentations: Past Approaches and Lessons Learnt

Overview – Lex Cogle (Session chair)

- Context – GBR catchments.
- Short Term Modelling project – what can be used for sediment, nutrient targets? Local data and knowledge, extrapolation of data to other scales, temporal and spatial interpretations of processes for models.
- Previous efforts:
  - Moss et al., 1992
  - SedNet – NLWA, Brodie, Bartley, Henderson, STMP
  - EMSS – Ellis, Searle
  - HSPF – Heather and Richard in Johnstone River
  - CMSS - Heather and Richard
  - CREAMS (Fitzroy)
  - Perfect, APSIM
- Scenarios – can only be developed in consultation with end users.
- Data cycle
- Reflections – significant work and achievements, model choices driven by expectation and what uncertainty is acceptable, level of complexity, spatial and temporal variability, need for more and more data, communication at all levels.

EMSS and SedNet – Douglas Shire (Tim Ellis, CSIRO)

- Modelling results in the Douglas Shire were not used. Why not? The models were driven by little or no data and as such were unreliable and untrusted.
- Expectations of the project were unrealistic. Given the time frame and the resources it was a good preliminary project but was perceived to be able to be much more definitive that was possible.
- Wrong scientific and management questions, driven by funding timelines. Poor administrative structure for the project.
- Lack of flexibility with the commitment to large complex models to alter scientific and community questions as the project progressed.
- Need to look at linkages between elements and systems at different scales.
- Important to have capacity to combine elements in different ways. Nested approach.

Questions

- Lex - Douglas Shire – difficulties? Concerned with water quality modelling.
- Rebecca - Biodiversity not a priority at the time – asked to set WQ targets – triple bottom line not applied. Step forward – work on triple bottom line approach.
- Freeman – need for mesoscale experiments.

SedNet and EMSS - Fitzroy (Ross Searle, NRW)

- Drivers – public policy pushing community involvement, Maroochy sugar mill closed down, Moreton Bay Report Card, EMSS applied across SEQ Catchments but not appropriate at all scales.
- Established Maroochy community monitoring team.
- Series of workshops to inform community – what is the model and why use it and how?
- Good access to a wide range of datasets.
- Limitations - Appropriate in rare circumstances, significant work involved, large team, transparent process – exposed weaknesses.
- Benefits – improved community understanding, substantial expertise, built relationships amongst team.
- Range of views from participants – video clips.

- There was some concern in the community about the level of uncertainty present in the model predictions.

Rebecca Bartley

- *Herbert* – good news story – emphasises need for long term planning. Significant measurement data existing in lower Herbert and set scene that sufficient data to run model. Tracing data to test the model. Identified future development areas in the upper catchment. Contrast to *Douglas* scenario – limited data and existing work. Data, tools for validation, monitoring.
- Needs underpinning monitoring, investment commitments.
- Clearly define questions, stop mismatching needs and models. Map out appropriateness of models to meet needs.

Heather Hunter, NRW

- With Richard Walton – *Johnstone* catchment. Funded in 1990s as part of pilot study of ICM. Social environment – was then still fair degree of denial regarding reef impacts. Implemented an intensive monitoring program to identify sources sediment and nutrients. Set up event based monitoring program and set up HSPF model, calibrated using monitoring data.
- Crucial to have supporting monitoring dataset.
- CMSS not suitable to draw on data from elsewhere – used local datasets for HSPF.
- Communication of results was challenging – twisted slant of results. Can't rely entirely on models – engage the minds of landholders to support results.

Cameron Dougall, NRW

- *Fitzroy*. Lack of knowledge of catchment behaviour and great variability across landscape.
- Cultural beliefs and paradigms of how catchments behave – challenges for communications.
- Modelling has a bad name – caught up with perceptions and realities of certainties.

Banti Fentie, NRW

- *Burnett Mary and Burdekin*. Strengths of STMP – communication framework established early in process to engage community and alleviate negative perceptions of modelling and mistrust.
- Limitations STMP – challenge of including socio-economic components and understanding social implications of various scenarios.

Panel Overviews (Bartley, Hunter, Dougall, Fentie)

- *Communication*:
  - Demonstrated examples of importance of local ownership and engagement in projects, eg. CMSS.
  - Douglas Shire learnings:
    - Science and modelling running on different time scale driven by funding; different to community timelines related to understanding and learning to adapt.
    - Important to develop a connection with community and willingness to adjust the project to meet their timescales.
    - Funding processes have not learnt issues with timing; need some flexibility in the system to accommodate those constraints.
    - Two fairly different answers between EMSS and SedNet – how to communicate that to the community and demonstrate that different answers are acceptable? How to get the issue of consistency in modelling approaches to generate similar answers?
  - Fitzroy: Engaging community assisted to manage issues around uncertainty. Understanding of catchment processes less than anticipated. Managing expectations of what project limitations are from the outset. Identified areas where further work was required.
  - Burnett Mary: Challenges where gully erosion prominent and mapping was inaccurate – local knowledge important.
  - EMSS – important to keep engagement throughout life of project.

- *Complexity*:
  - More complex models are not necessarily the solution. Need level of reality – understanding processes and responses to change – some level of complexity is required. Need to attempt to mimic complex processes, eg. Gully erosion.
  - Dichotomy between policy makers who think they need complex models and modellers who know that they don't have the data to dirve mode complex models – how to resolve?
  - If considering bounds in complex models – consider whether some more simple approaches with expert thinking end up with similar results.
  - If representing complex systems can be problem to use simple models – depends on the question. Eg. USLE.
- *Data availability*:
  - Lack of supporting data in many areas, especially in terms of consistency across scales and parameters.
  - Need to use best available data which may require use of external datasets – but need to make results locally relevant and believable.
  - Many complex models relying on data derived from other sources.
  - Monitoring critical for validation, often limited funding.
  - Capacity to integrate data into models, and integrate models across the landscape.
- *Uncertainty*:
  - Need to communicate carefully and manage expectations of users.
  - Not as concerned about uncertainty as opposed to risk. Complex decisions but level of uncertainty can be high.
- *Long term strategies and funding*:
  - Need for long term modelling approaches.
  - You get what you pay for – not necessarily good outputs if you put a lot of money towards a project with short timeframes.
  - Need to define the key question and therefore the best model; in context of timeframes and funding.
  - What next? What do the clients expect the models to do next? What do the scientists expect to do next? What is required to achieve next step?
    - Short Term Modelling Project – build up of acceptance in regional groups of value of modelling.
    - Iterative process; learn more – develop better models.
    - Community perspective – more work required? Understand need for continuous improvement.
    - Regional body perspective – giving some confidence on spatial prioritisation; now need to move to other scales and broader scale dynamics, management practices.
    - NRW review of catchment modelling undertaken by Prof. Rodger Grayson and scope future modelling needs. Need for ongoing improvement, communication and collaboration.

Attachment 4: Overview of Presentations: Sediment modelling and System Lags

Modelling sediment delivery from hillslopes (Peter Kinnell, University of Canberra)

- US example – identification of hotspots
- Most catchment models depend on USLE
- USLE – doesn't deal with slope deposition so sediment delivery ratio (SDR) commonly used
- Relationship between erosion and SDR not constant but assumed to be.
- US – RUSLE2 – designed to predict movement on whole hillslope using sediment transport capacity approach
- Other models – ANSWERS, AGNPS v5 also use sediment transport capacity approach.
- SDR most commonly used. Transport capacity approach more scientifically robust.
- Strategic research area.

Delivery from paddocks: Hillslope erosion and sediment properties (Mark Silburn, NRW)

- Key areas of research:
  - spatial runoff and sediment water balance models
  - suspended vs bedload generation
  - sediment properties
  - nutrient enrichment ratios
- *Do water balance models have a role?*
  - Useful in salinity work and deep drainage.
  - Can be applied at paddock scale, then "add up" paddocks to make catchment (eg 2Csalt).
  - Assumes land use effects on hydrology eg. Event Mean Concentration.
  - Runoff from water balance – erosion, measure sediment concentration.
  - Proportion of fines increases with increasing cover.
  - Sediment velocity distribution across 6 soil types in Qld – characteristics relatively similar; also data for 5 soils in Mary-Burnett.
  - Possible to do spatial runoff and sediment water balance models, Suspended sediment vs bedload, nutrient enrichment.
  - Available if you need them.
- Need data/models to derive EMCs and loads for sub-catchments, related to land use.

Riparian interception (Peter Hairsine, CSIRO)

- Hairsine 7 models – not suitable at catchment scale; plot and plume scale.
- Limited investigation riparian interception – highly variable lag times. Time scales of months – sediment becomes soil in riparian zones; little field work on remobilisation.
- Riparian zones vary significantly in characteristics.
- Transition between hillslope and deposition point.
- Understanding:
  - McKergow et al – tropics, GBR, horticulture, grazing
  - Newnham – models
  - Hairsine et al – tropics, stock access
  - Much international reference work
  - Stock access is a major issue
  - Roads and farm tracks compromise riparian zones – high sediment sources
- Key limitations:
  - We have transferred knowledge from plot measurements to plot scale with little understanding.
  - Moderate understanding of sediment and hydrology.
  - Pathogens, solutes and organic matter are key weak areas.

- Spatial distribution of processes and the effect on how our catchment models represent these.

Storage within stream systems, Burdekin catchment (Rebecca Bartley, CSIRO)

- MLA funded project in Burdekin.
- Used scenario analysis tool at smaller scales. SubNet.
- Set up new monitoring sites – deposition and runoff in gully and hillslopes, channel storage.
- Hillslope – mean cover on catchments not that representative – range and distribution of cover more important.
- Developed sediment budget. More erosion from gullies than anticipated; bank erosion higher than modelled. More coarse sediment off hillslopes (USLE assumes fine sediment loss dominant).
- Storage in gullies and stream beds – not well addressed. Temporal lags exist in the system.
- Variability between years – effects of extended drought.
- The total predicted erosion from RUSLE decreases as grid size increases, due to smoothing of the input variables (particularly slope and percent cover).
- Estimating HSDR using the travel time approach works reasonably well up to a grid size of 50 m (2500 m^2). Beyond this, it breaks down.
- This is primarily due to the model grid size approaching the threshold area used to define channels. Above ¼ of the channel threshold area (1 ha in this study), the model behaves unpredictably.
- If input data are not available at less than ¼ of the channel threshold area, we recommend using a constant HSDR everywhere in the catchment.
- Only when input data are available at a scale less than ¼ of the channel threshold area should a spatially-explicit HSDR model be used.
- It is the arrangement of cover, rather than average cover, that may be a more important influence on sediment yields at the hillslope scale.
- The location of bare patches close to the stream network is important.
- Applying a variable HSDR is only possible when grid cell size is available at a scale less than ¼ of the channel threshold area.

Dams as sediment traps (Brad Sherman, CSIRO)

- Approaches to model sediment trapping in dams not well developed.
- Algorithms for modelling sediment traps – computes residence time depending on average annual flow and drop out over time. Based on data from storages in US. In stratified reservoirs algorithm does not hold. Rainfall input in summer months affects stratification – different if well mixed.
- Reservoir models – interaction stratification, coagulation etc. to estimate true trapping capacity over time – available and can be plugged into existing models. Eg. Brad and Jon B in Burdekin.

Lags in sediment and nutrient export – the example of Fitzroy Estuary and Keppel Bay – A Highly Episodic System in Dry Tropical Australia (Phillip Ford, CSIRO)

- Nutrients generally attached to fine sediments in estuarine system.
- CRC project – Fitzroy estuary. Mean particle size 1 micron, highly variable flow between years, highly episodic. Barrage 60km upstream – extent of estuary.
- Flood event – freshwater plume pushes saltwater to mouth – 3-4 m deep freshwater layer can extend up to 20 km offshore during events. Nutrients desorbed from particles – dissolved nutrient mixing resulting in high primary productivity (high chl). Adsorbed into particles.
- During wet years as a result of overbank flow in the floodplain, proportionally less of the sediment entering the Fitzroy Lagoon is exported to the GBRL.
- Mixing, transport and resuspension of mud. Net transport of fine sediments back up estuary (velocity inward tide is greater) – flux up estuary. Residence time in estuary several months.
- Model to calculate flux and net load of sediment particles in and out of system.
- Substantial differences between 'wet' years and 'median' years.

- Impact of adding additional dissolved nutrients also includes elevation of background concentrations through mixing.
- Particulate nutrients mainly deposited in coastal areas.
- Deposited particulate nutrients slowly remobilised into dissolved forms (partial).
- Subsequently remobilised into coastal creeks and transported northwards and seaward (time scale: years).
- Dissolved nutrients - Rapid uptake by phytoplankton (time scale : days).
- Repeated cycling through detritus and phytoplankton (timescale : years)
- Ultimate fate - export and burial.
- Inter-conversion of particulate and dissolved nutrients.

Attachment 5: Overview of Presentations: Processes missing from nutrient models

Overview – (Brad Sherman, CSIRO - Session Chair)

- Uncertainty in input data – eg. Fitzroy – no spatial pattern to errors; considered average of measured values versus values from ASRIS database – measured is 80% higher.
- Lack of differentiation between land uses, soil types, limited empirical database to calculate EMCs.
- Dissolved nutrients are immediately bio-available.
- It takes 14-15 hours for particulate and dissolved nutrients to come into equilibrium in the stream system.

The role of groundwater (Keith Bristow, CSIRO)

- Groundwater systems throughout catchment – coastal and upstream; differences in surface and groundwater interactions.
- Connectivity between flow paths – interdependencies. Where do materials end up and in-soil chemical and physical processes? Transformations?
- Bores – complicate relationships.
- Aquifer more transmissive in vertical profile than originally thought – important for understanding fate.
- Burdekin case study – considered nutrient application, discharge, uptake, bore concentrations – to understand discharge from the system.
- High proportion elevated nitrate concentrations in bores, high proportion increasing concentrations. Accumulating nitrogen in groundwater; also some areas low levels.
- Salinity – overall level relatively constant; distribution varying.
- Does not flush from system as easily as previously thought.
- Must set and meet groundwater quality targets – quality and quantity.

In-soil transformation (John Armour, NRW)

- Factors affecting nutrient movement – very important, nutrient management
- N concentrations from leachate from banana properties, various N application rates. Matched rate of application to plant growth rate. High application results in high concentration N below root zone.
- Tully bananas – rainfall increasing, increased N application, increased N leachate – direct relationship between them.
- Sth Johnstone – cane. Rapid reduction in groundwater in short periods. N load and N discharge to streams – significant movement. High N concentrations with increased rainfall.
- Phosphorus – Tully bananas – high variance FRP.
- Sub-surface N movement major loss pathway in well-drained soils. Significant challenges for improved N application; reduced rates.
- What are the pathways to the reef?
- Research has demonstrated good reduction in nutrient transfer to groundwater with reduced applications. These applications have been related to productivity in relation to bananas and cane; no difference in fruit quality and limited variation in productivity.

Riparian zone denitrification (Heather Hunter, NRW)

- Developed Riparian Nitrogen Model based on detailed lab and field experimental work. Initially SE Qld, also Victoria, WA.
- Total flux of water and nitrate exposed to active sediments; slope and conductivity of soils, average denitrification rate in root zone – calculate nitrate removal.
- Incorporated RNM as filter module in E2 – subcatchment scale. Limitation – E2 didn't specifically model nitrate.
- RNM can help assess the buffer width and rooting depth to aim for. Varies between catchments.

- Not all riparian zones same – certain points on channel where shallow discharge is most likely to occur. Developed Riparian Mapping Tool based on the Riparian Rehabilitation Index – helps identify reaches within sub-catchments where rehabilitation has the greatest potential to reduce delivery of nitrate to streams.

Attachment 6: Summary of sediment and nutrient challenges developed by workshop participants

Sediment dynamics

Addressing storages in catchment processes including dams (Brune equation), floodplains etc
HSDR – cover arrangement in space and processes – improving understanding of processes and representation in models
Need to revisit USLE as a way of predicting erosion
Describing 'storage phases' and 'flushing phases'
Need to determine importance of and lag times due to channel deposition
SDR – Spatially variable, incorporate variable (spatial, temporal) cover, including cover type
Need a temporal signal in gully erosion as they grow and mature through time
Measurements required include air photos, sediment dating, land cover data, LIDAR, remote sensing of turbidity.

Hydrology – including groundwater and receiving waters

Moving from long-term science (monitoring and modelling) to event-based
Space and timelags associated with groundwater
Groundwater – fate and dynamics
What time lags are there? (perfect nutrient management reflected in water quality in ? years)
Need to assess importance of groundwater components at reach regional context
Capturing temporal dynamics of system including hydrology

Dissolved nutrients and contaminants

Big picture – lack of nutrient budget (high and low flow)
Nutrient speciation is everything for ecological response. Need to move from considering just total nitrogen and phosphorus to consider speciation of nutrients
Need to relate land use and land management to nutrient concentrations and loads

Temporal and spatial scaling

Important to collect data over the long-term
Improving our understanding of landscape processes at a finer resolution (including results of land management activities)
Is bedload important? If we aren't interested in bedload can we change the approach (time scales)?
Linking hillslope science with instream dynamics – the interface of dynamics
Capturing temporal dynamics of system including hydrology
Nesting (scales) – management matters
Event-based monitoring and modelling is also required

Data and models

Landscape is generally poorly characterised, eg. Rainfall, soils, meat (cows), stock rates
Improve input data – soils, hydrology, climate, slope
Knowledge base limited – need to improve process understanding (high powered research / investigation / models)
Need to understand which pathways / processes are important and where (regions, areas, scales, management questions)
Capture variability in data – includes monitoring
Continuity of 'right' monitoring to input / trace movements / levels of nutrients

Important to include remotely sensed data as input to models

Incorporating uncertainty

Determine confidence levels – a need to have confidence in the delivery of restoration in a particular landscape
Need to interpret model results and present uncertainty to end users in a way that is understandable to the non-expert
Need to have quantitative measures of uncertainty included on all model results as a matter of course

Links to land management and policy

Long-term strategy for model development seems to be missing
What is change in water quality for change in management practice
Management practice links to nutrient losses, including nutrient speciation
How to represent management actions, eg. Filtering by coastal wetlands etc
Link between nutrient management and productivity and loss to environment
Nesting (scales) – management matters

Attachment 7: Responses to the key challenges of nutrient and sediment modelling: Suggestions for the way forward

1. Sediment dynamics

User needs	Challenges	Way Forward	Tools
Depends on question	• Pressing need for improvement in Hillslope Sediment Delivery Ratio • Revisit USLE parameterisation with better topography, soils (including size) and cover information • Improve gully model to recognises temporal erosion • Deposition within the channel: a neglected factor? • Bank erosion and channel dimensions in the GBR catchments • Transfer southern experiences to GBR Catchments • Reservoir trapping _ a study to test the Brune equation and improve daily models • Community collected data – emphasises ambient condition – could be uploaded with much benefit. Potential for other forms of monitoring (eg. Farm dams, formation of gullies, streambank) • A need to have a database of sediment size (impacts and future models) • Mapping of floodplain deposition or stripping after events • Response in aquatic ecology field	• Measurements: – sediment dating – time series of photos – Remote sensing (RS) ground cover including bleached cover – LIDAR data for gully and stream banks – coring of all major reservoirs – RS of turbidity and chloride will lead to a revolution in event-scale modeling (including ground truthing with station data)	• Trend analysis tool, so we can pick up changes in land management e.g. generalised additive tools from salinity work. • Better quantification of bleached cover, and whether things are a perennial or annual species. • More information on the response of land management changes on sediment and nutrient loads. • Improving remote sensing capacity of water quality data. • Improve and evaluate the reservoir tool. • Need for parameter libraries across a range of areas (e.g. SILO) and projects. E-Water will be the main node for this delivery.

2. Hydrology

User needs	Challenges	Way Forward	Tools
• Policy and management to use information • Know the water balance • Fluxes between groundwater and surface water • Quality of water moving through catchment and timescales • Fine scales • Characterise key features as upper, mid and lower (coastal floodplains) components of catchments and be able to understand exceptions • Pictures of catchments – knowledge platforms	• Connectivity between surface and ground waters – where is the base flow critical and temporal nature • Base flow • Build on salinity work • Draw on groundwater work in other regions • How to incorporate wetlands into the system • Saltwater intrusion	• Make better use of multiple lines of evidence – developing indicators, surrogates, synthesised information • Understanding quality – conservative, reactive, tracers, use of quality helps to get the fluxes right • Identify and obtain key data – temporal and spatial definition • Understanding and clarify questions – scientific suite of tools or synthesised, simpler products used at a broader level for generating information	• Remote sensing: – Precipitation – EW – architecture, salinity – ET – Finer scale DEM – stream networks – Ocean sensing networks (upwelling, wonky holes) • Really need tight (iterative) link between data collectors and modellers – Land use features eg. Irrigation, GCTB in cane – Airborne geophysics / ground truthing with decent bore holes • More sophisticated hydrographic network – Real time monitoring – WRON • Need WQ tools – SW – EW

3. Dissolved nutrients and contaminants

User needs

- Defining the user – small scale vs catchment scale - various needs across scales (eg. regional, agency wide)
- Need to focus on bioavailable components versus TN/TP approach
- Include timing of delivery
- Scenarios of change

Challenges

- Better define concentration and loads from different land uses (bioavailable components) including behaviour of pesticides (partitioned into dissolved and particulate) - gathering that data, identify land that is of a particular type and define, separate event and ambient.
- Relationship between groundwater and surface water interactions – take lessons from salinity and groundwater monitoring
- Improve patchy monitoring of streams – esp. pesticides
- Reactivity of organic P?

Way Forward

- Hydrology – assessment of region by region to understand which pathways are important
- Use empirical approaches to explore timing of delivery (versus explicit modelling)
- New tools to understand movement eg. Isotopic tracers to determine if denitrified or not
- For groundwater, keep broad-brush approach and focus on areas where know issues exist
- Pesticides – need to understand behaviour, partitioned into dissolvable and particulate
- Improve ability to develop new products.

- Hydrology – assessment of region by region to understand which pathways are important
- Empirical approaches to explore timing of delivery (versus explicit modelling)
- New tools to understand movement eg. Isotopic tracers to determine if denitrified or not
- Improve ability to develop new products.
- Sampling frequency
  - First flush and 2 across hydrograph? OK for TSS – not for nutrients – loses lag of groundwater inputs
- Remote sensing
  - inland not likely to be useful?
  - useful for marine
- Isotopic ratios for tracing organic carbon – C3 (other) C4 (cane)
  - Tully trial commencing now

4. Temporal and spatial scaling

User needs	Challenges	Way Forward	Tools
• Fine enough scale to enterprise level • Need for aggregated results across scales	• Data resolution • Opportunities for RS • Event monitoring and modelling • Integrating models across scales • Need answers now - incremental improvements	• Data collection ongoing • Apply a nested approach to accommodate different scales • Getting started with funding commitments	• Soils data set is limited can we improve with radiometrics and modern techniques • Deconvolution of signals from radiometrics needs more research • Rainfall is daily but use of radar will be useful in some areas to get better spatial resolution • Highest resolution that can be afforded • Uncertainty will increased as interpolation increases • Crop data will depend on processes

5. Data and models

User needs	Challenges	Way Forward	Tools
• Models and modellers • Spatial designation – how fine? • Continuum between data and models and design and action; scoping and accuracy; confidence and relevance • Data quality assurance (eg. Rainfall reliability) • Event based monitoring • Event based/seasonal design approach ability • Transferability and climate variability • Describing time lag times – targets set on onground actions	• Institutional constraints with data sharing • Need for broad and fine scale data, eg. Longitudinal sampling • Getting funding for mesoscale experimentation and monitoring • Timeframes • Reliability / instrumentation • Getting relevant data and validation for RS data • Incorporating event based information into models and design approach • Linking between scales	• Remote sensing – rapid and comprehensive data acquisition • New sensors? • Data processing and handling • Need assessment of what could be achieved with new RS data • Online population of models • Taking advantage of new computational efficiency (eg. Dual processes) • Linking new questions and monitoring Ways forward: • Collaboration between modellers, data, management people • National approach to data transfer and handling – WRON? • Strategy for collecting the right data in the right place eg. Scale	• Uncertainty in raw data – no property propagating?? (not looking at direct measurement error) • Quality control/assurance eg. DEM (25m) • Accuracy and precision eg. Spatial accuracy of streams • Rainfall (gap filling and accumulation – rainfields characterise events • Fluxes and concentrations • Loads • Sampling density (spatial and temporal) • Land use and what it describes – huge uncertainty about stocking rates etc. (relates to bare ground cover and index) • Remote sensing data – atmospheric correction – Uncertainty in ground truthing – sampling strategy • Time and funding etc – determine sampling density • Uncertainty in “linking/scaling” – is this known? • Temporal scale addressed by turbidity • Sampling standards, protocol, design, quality control, analysis, interpretation • Remote sensing – will it help? • Matching question and time / $ available to sampling strategy • Process: 1. Decide precision or standard; 2. identify density required (space and time); 3. Define methodology; 4. Secure funding.

6. Uncertainty

User needs	Challenges	Way Forward	Tools
• Qualitative measure of confidence; thresholds of concern • Exception with target setting, need numerical uncertainty	• Estimating impacts of management practices and rare or extreme events • “Certainty” assigned to correct scale with caveats on other scales	• Data and process knowledge	• BACCO, GLUE

7. Links to management and policy

User needs	Challenges	Way Forward	Tools
• Requires clear definition	• Multiple users • Articulate user needs • Understand capacity • Manage expectations • Confusion • How to facilitate this dialogue? Lots of good reasons why modelers, managers and policy-makers don't communicate well	• A balanced portfolio of short-term and long-term science strategies • Long-term strategy for development of next generation is missing? • Version control • Opportunity/risk of using models to facilitate dialogue about understanding catchment processes • Iterative processes between models and other evidence • Need more win-wins, win-draws ie palatable options • Need a transparent reflection of on ground action (not a background hack) ie ABCD land conditions • Presentation needs to reflect audience needs ie management practices, ecological impacts eg SIMReef	Understanding the ways that models are used in decision-making: • Role for complexity and simplicity • Need for profound simplicity not dumb models (what is the insight?) • Models (and other evidence) used in social processes (don't overvalue the role of the models) Complexity to simplicity – pesticide risk in cropping systems: • What amount of pesticides are moving (detection rates 80% of samples), and how do we reduce it? • Nested monitoring program 5 yrs • Model SWAT + graphical output device + BMP manual + then simpler version of the model to communicate dynamics • Simple risk-assessment tool (1 page, 4 bars, self-assessment) - Runoff, landscape erosion, chemical load, filtering capacity • And management options to reduce risk • Raise awareness of invisible issues (at minimum) – appropriate to audience and time • Transferrable approach Spatial outputs and social processes for prioritising investments – FBA: • EMSS (and later Sednet) • Salinity hazard assessment (and risk in future) • BAM mapping (biodiversity assessment) • Pest mapping (pestinfo)

- Overlay X neighbourhood catchments
- Discussions at sub-regional board (including uncertainty)
- Level of community involvement
- Rank neighbourhood catchments for each
- Prioritise areas for next years focus (not necessarily top ranked)
- The lucky catchments are then invited to look at information (wider range), provided technical advice and develop EOIs for activities – decision by board
- Models also used to explore outcomes of agreed actions – to receiving waters

Models driving major investments - Moreton Bay:

- Catchment & receiving water models
- Long-term, comprehensive monitoring to evaluate progress against targets
- Used to prioritise management actions (through science panel and community/industry/govt groups – structure & process)
- Simpler Ecosystem health report card – communication for community engagement
- EMSS designed to be user friendly input & output (key to effective engagement)
- Stormwater policy change and major investments in STP upgrades

Knowledge-based reef policy – a vision for the future:

- Receiving water ecological models to understand potential recovery/protection paths
- Quantification of potential WQ benefits based on existing land use & management practices.
- Costs to implement that.

- Where can we get to? Is that acceptable? What level of investment is required?
- Social discourse considering trade-offs.
- Practice change or new practices? Land use change or new land uses? Full accounting of costs in the long-term.
- Can we define acceptable environmental outcomes and work back to achieve that (visioning)?

Attachment 8: Overview of Presentations: Tools for sediment and nutrient modelling

Uncertainty in SedNet (Petra Kuhnert, CSIRO)

- Focusing on Burdekin at 250m resolution – estimate loads incorporating uncertainty.
- Look at major inputs to models, eg. SedNet – propagate error through river system – standard errors.
- RUSLE – eg. Hillslope erosion. Higher uncertainty occurs where hillslope erosion is high.
- Developing statistical approximation to apply distributional form to establish uncertainty of each factors.
- Can establish links between uncertainty in hillslope erosion and rainfall erosivity error.
- Gully density – regression tree analysis. Current predictions appear to be quite poor.
- Compare CUBIST predictions to a local scale – low match up – broader scale approaches not as useful at regional scale.
- BACCO – Bayesian modelling.
- Relationship between SS and turbidity. Error if sample at lower frequencies with grabs versus logger – and what combination is optimum? Further work is required.
- How to incorporate information to get better understanding of parameter uncertainties? Suggest we bring in measured data, eg. R factor. Important distributions. When is certainty most important? How much certainty is sufficient to inform management decisions? Need dialogue.
- Need to explore best way of expressing uncertainty – visualisations (eg. Traffic lights). If targeted hotspots in every source variability in sites. Finessing style of map important at fine scale but need to step out at bigger scales to indicate certainty (eg. Upper catchment) – stratification of results to assist with strategy for investment. Depends on what we are trying to do with uncertainty – prioritise areas and investigate variability. Show that uncertainty is higher in areas where want to prioritise – careful in presentation of data to avoid problems with misinterpretation.

E-water uncertainty project – SedNet sediment budgets (Scott Wilkinson, CSIRO)

- Quantifying uncertainty is important to guide use of model results, prioritise model development and data collection.
- Used monte-carlo analysis of SedNet to estimate the uncertainty coming from uncertainty in model inputs and parameterisation.
- Uncertainty in spatial patterns is higher where there is a smaller range of erosion across catchments.
- Evaluating model uncertainty using data includes uncertainty from model inputs and also from imperfect model structure. Because there are little data on erosion rates, use surrogates including sediment yield estimates, bed material accumulation, sediment tracers.
- Uncertainty tends to decrease as catchment area increases because errors in one sub-catchment can cancel errors in another.
- Targeted data collection to refine model parameterisation is the best way to reduce uncertainty in model outputs.

Loads tool and parameter library (Nick Marsh, EPA)

- Loads tool provides a library of methods for calculating loads from sediment concentration and streamflow data.
- Parameter library may assist in the calibration of models.
- Analysis of SS data Qld wide – get more out of existing datasets; using turbidity loggers as surrogate for SS – consistent relationships, most variability within sites.
- Hydraulic geometry – analysed data across Qld – coefficient bankfull width and depth much the same as Victoria – can extrapolate results.
- Ecological response modelling – response to sediment and nutrients – link into existing catchment models.

- Loads routine – use to determine appropriate monitoring for events. Set up assessment of 19 sample events to assess monitoring design and application of most appropriate model. Can limit to 4 samples as long as at least 2 are before the peak.

Remote sensing of groundcover (Peter Scarth, NRW)

- Bare Ground Index and Foliage Projective Cover are based on Landsat data. Ground-truthed using 300 sites across Qld. Assess ground and canopy – 100m long x 100m high.
- SLATS Landsat archive – being re-calibrated.
- Not confident measuring ground cover under 20% or more foliage projective cover.
- Validation of indices – eg. AussieGRASS – model cover.
- Note that foliage projective cover is not the same as crown cover – 30% FPS is roughly the same as 60% crown cover.
- MODIS – Charters Towers MLA project – 1km resolution. Will increase the temporal resolution of data from annual (Landsat) to 16-day (MODIS).
- Ongoing product development – time series, LIDAR data gully and streambank erosion.

Attachment 9: Overview of Presentations: What are the desired characteristics of a sediment and nutrient model for the GBR region?

Overview – Freeman Cook, CSIRO (Session chair)

- Systems Models will be useful in policy making but:
  - They can only be used for scenario testing;
  - Represent one input into the decision making framework;
  - Social representation in these models is likely to be 'rubbery' well into the future;
  - Seduction by the graphic interface should be avoided.
- With complex systems, monitoring is essential, prior to and after intervention:
  - Modelling can help to ensure we monitor the fastest responding variable and give insight into the system behaviour.

E2 and catchment modelling toolkit (Geoff Podger, CSIRO)

- E2 promotes a new way of modelling:
  - Building models applicable to data;
  - Building models applicable to questions;
  - Not being limited to one approach.
- E2 provides a means for collaboration in model development. It is not meant to be a one-size-fits-all model, but rather a way of linking models together.
- E2 demonstrates a way forward for a consistent approach to modelling across Australia.
- The Catchment Modelling Toolkit provides a easily accessible and efficient way of delivering and supporting software.
- E2 development in eWater:
  - September release Version 1.3 (some enhancements based on user comments)
  - Driven by development of eWater products
  - Enhanced reporting
  - Scenario management
  - Multiple run capability
  - Linking with stochastic climate models
  - Pathogen model plug-in (testing).
- eWater product development
  - P1/P2: River Operations and Management - will encapsulate IQQM,MSM-BigMod and REALM functionality and provide a tool for daily river operations
  - P3: Cluster scale urban management
  - P4: Regional scale urban management
  - P5 (WaterCast): Catchments - Common Conceptual Model for modelling constituents
  - All Products are supported by a common river system modelling framework (E2)
  - Interfaces will be built to meet user needs but can be configured to any one of the other products..

Attachment 10: Overview of Discussion: Issues for coordination

Lex Cogle, NRW

Example – Short term modelling project (STMP) implemented to address action in Reef Plan. Cross regional delivery of model outputs that delivered successful outcomes. Important elements in the process which led to this project being successful included:

- Subgroup developed proposal for *high level support* – Deputy DG, JSC
- *Confidence to proceed*. Target setting very controversial in 2004/2005 – clear need and support. Constraints of timing. Need to focus on the outputs required.
- *Multi-agency team* (20 people), across regions, built on previous CRC project.
- *Good communication plan* – within team, clients and high level. Built trust with NRM regions; different approaches depending on group.
- *Built capacity* across regions.
- *Utilisation and access to available datasets*.
- *Joint commitment*.

Mike Grundy, WFHC CSIRO

- New Theme process – commencing July 2007.
- Four Themes – Healthy Water Ecosystems, Urban Systems, WRON, Better Basins Futures – all have work in Qld.
- Need to identify future Theme structures and opportunities for collaboration – new directions.
- NRW QSCAPE, Leasehold Land Strategy, Salinity modelling work – at point where need to re-focus.
- NHT investment from Regional groups.
- E-Water
- AIMS triennium funding March 2007
- CSIRO – lead joint process to develop collaborative arrangements.
- This workshop can inform multiple planning processes.
- Should this sort of workshop become an annual event?

Rachel Eberhard, Reef Water Quality Partnership (RWQP)

- Range of diversity within and between agencies and organisations.
- RWQP – not separate entity; team within partner institutions and relatively restricted.
- Role of RWQP – facilitation and coordination. Act as neutral broker.
- Priority actions – including catchment modelling. Developing strategy for each action;
- Timing – multiple opportunities. GBRMPA Marine Monitoring Program - receiving water modelling gap; Qld load monitoring – Cabinet Submission, next round of regional investments.

Scott Crawford, Burdekin Dry Tropics NRM

- Question: Why would we want to collaborate? Answer: Differences in language and required level of understanding and knowing what the other wants.
- Different levels of detail – much bigger picture - targets, interventions, costs.
- Example:
  - Established overarching project management ‘umbrella’.
  - Framework to apply modelling outcomes. Included users of models, users of outcomes.
  - Identifying what end needs were; process of how the results would be used.
  - Developed clear work specification. Is it technically feasible? And in timeframes? Cost?